BIDIRECTIONAL REFLECTANCES OF REGOLITHS WITH GRAIN SIZES OF THE ORDER OF THE WAVELENGTH. B. Hapke[1], D. DiMucci[1], R. Nelson[2] and W. Smythe[2]. [1]Dept. Of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260. [2]Jet Propulsion Lab., Pasadena, CA 91109.

Scattering and emission of radiation by regoliths with grain sizes d large compared to the wavelength l, when the particles scatter quasi-independently, are reasonably well understood. However, this is not true when the particle sizes are comparable with or smaller than l and interparticle coherent effects can be important, a situation that often occurs in the thermal IR. Nevertheless, many authors treat the two cases similarly. In addition, theoretical calculations [1] have indicated that certain regolith scattering properties, such as the angular width of the opposition effect, should be strongly dependent on d/l.

In order to understand scattering by particulate media with d ~ l, we have undertaken a multispectral study of scattering by hematite abrasive powders which span the range from d<<l to d>>l. Hematite is strongly absorbing at short wavelengths, so that by varying both d and l the effects of albedo on the scattering parameters can be separated from the effects of d/l. The porosities of the powders were all nearly the same, 85-89%.

The powders were viewed by a detector at e = 60^o from the normal and illuminated in the principle plane over a range of angles i between 70^o on both sides of the normal The phase angle g varied between 1^o and 130^o. The data were then fitted by an equation of the form (2)

$$r(I,e,g)=(w/4\pi)*\mu_o/(\mu_o+\mu)*OE(g)*[p(g)+H(\mu_o)H(\mu)-1],$$
$$OE(g) = 1+A/[1+(1/h)\tan(g/2)],$$
$$p(g)=(1+c)/2*(1-b^2)/(1-2b\cos g+b^2)^{3/2}+(1-c)/2*(1b^2)/(1+2b\cos g+b^2)^{3/2},$$
$$H(x) = [1+2x]/[1+2x*sqr(x)],$$

where r = bidirectional reflectance, w = single scattering albedo, μ_o = cosi, μ = cose. The quantities w, A, h, b and c are the parameters that were fitted. The particle phase function p(g) is a double Henyey-Greenstein function; c determines whether the particle is forward (c>0) or back (c<0) scattering and b determines the width and amplitude of the lobes. OE(g) is an opposition effect function with amplitude A and angular width h that includes the averaged effects of both a shadow hiding and a coherent backscatter opposition effect.

When an isolated particle becomes smaller than the wavelength its scattering efficiency decreases and its phase function is proportional to 1+cos^{2}g. Hence, if the particles in a powder behaved similarly, it would be expected that when d/λ < 1, w would decrease markedly and c ->0. This is not what is observed, as shown in Figures 1 and 2. All sizes of particles were strongly back scattering (c > 0) and the single scattering albedo increased, rather than decreased for small particles.

If the opposition effect is caused primarily by coherent backscatter, h would be expected to decrease as d/λ increases, while A should increase with w. Figure 3 shows that h is not correlated with d/l, which is what would be expected if a large part of the opposition effect is caused by shadow hiding.

These results show that particles smaller than the wavelength in a regolith do not scatter independently. Apparently, coherent interactions between them cause clusters of small particles to scatter like much larger particles. Although coherent backscatter does occur, as indicated in Figure 4 by the increase of A with w (and also by an upturn in the circular polarization ratio at small g, which was also measured, but is not shown), these clusters apparently dominate the scatteing and cast shadows that cause a shadow hiding opposition efect.

REFERENCES: [1] M. Mishchenko (1992), *Astrophys. Space Sci* **194**, 327. [2] B. Hapke (1993), *Theory of Reflectance and Emittance Spectroscopy*, Cambridge U. Press, N. Y.

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Fig. 1. Single scattering albedo

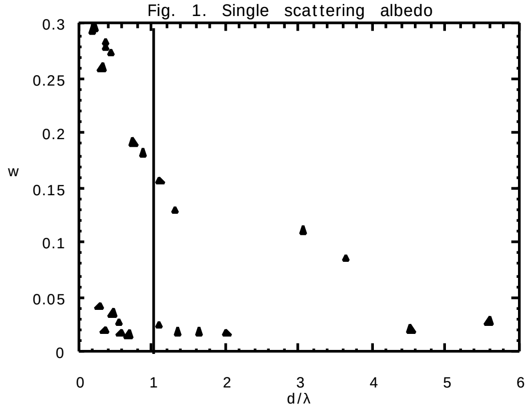

Fig. 2. Particle phase function symmetry factor

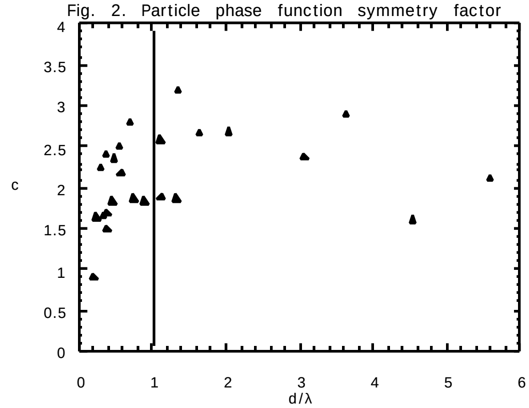

Fig. 3. Opposition effect angular width

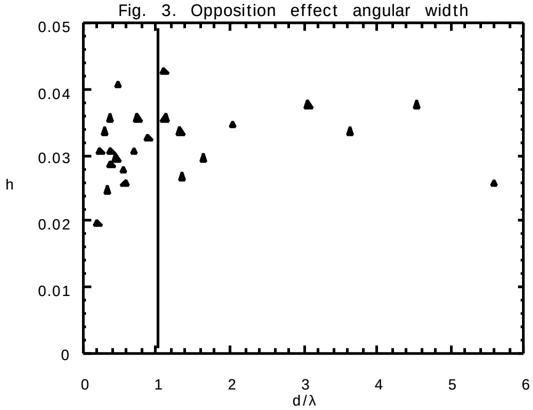

Fig. 4. Opposition effect amplitude